Feb. 14, 1933. S. S. GREEN 1,897,118

CIRCUIT CONTROLLER

Filed June 13, 1928

Fig. 1.

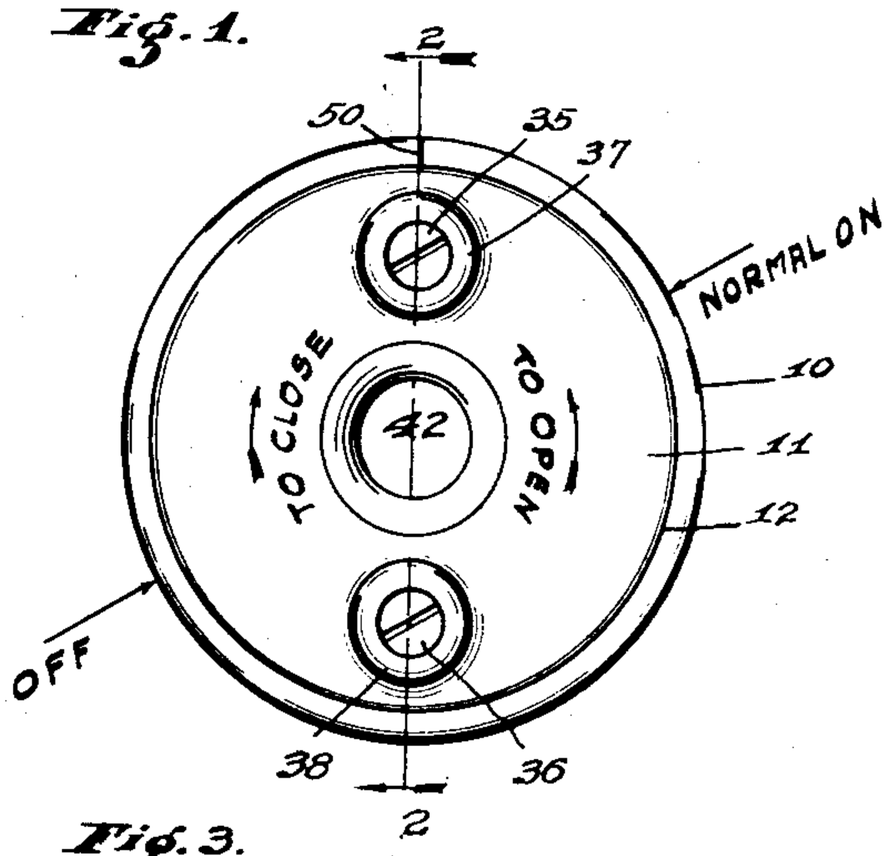



Fig. 3.

Fig. 2.

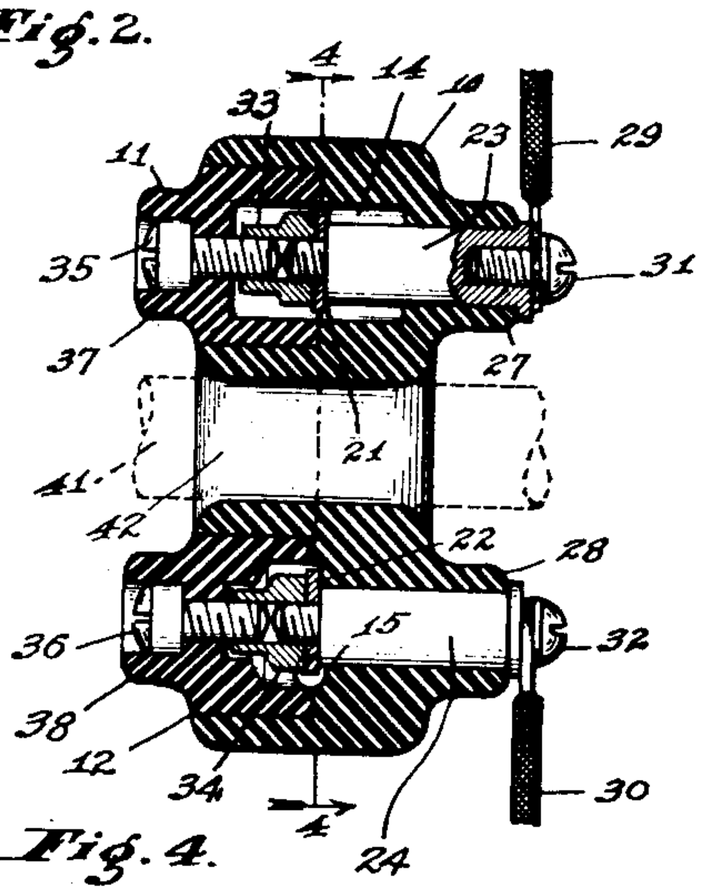



Fig. 4.

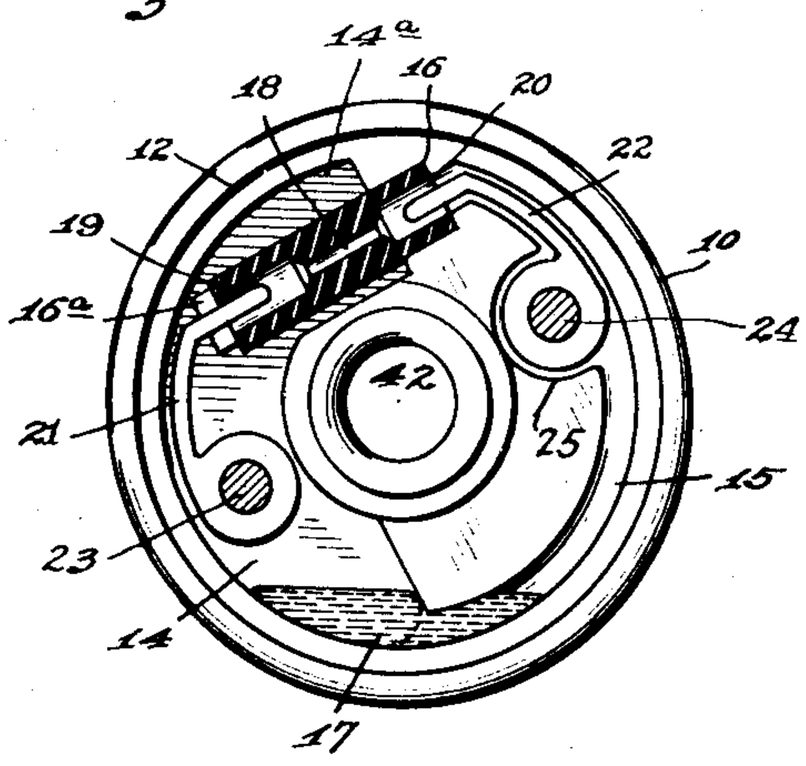



Fig. 5.

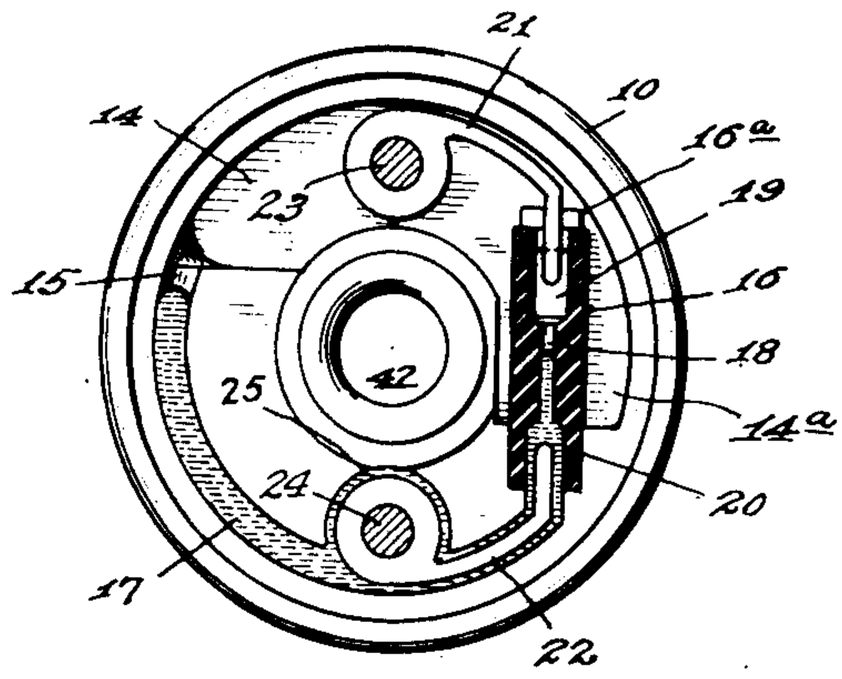
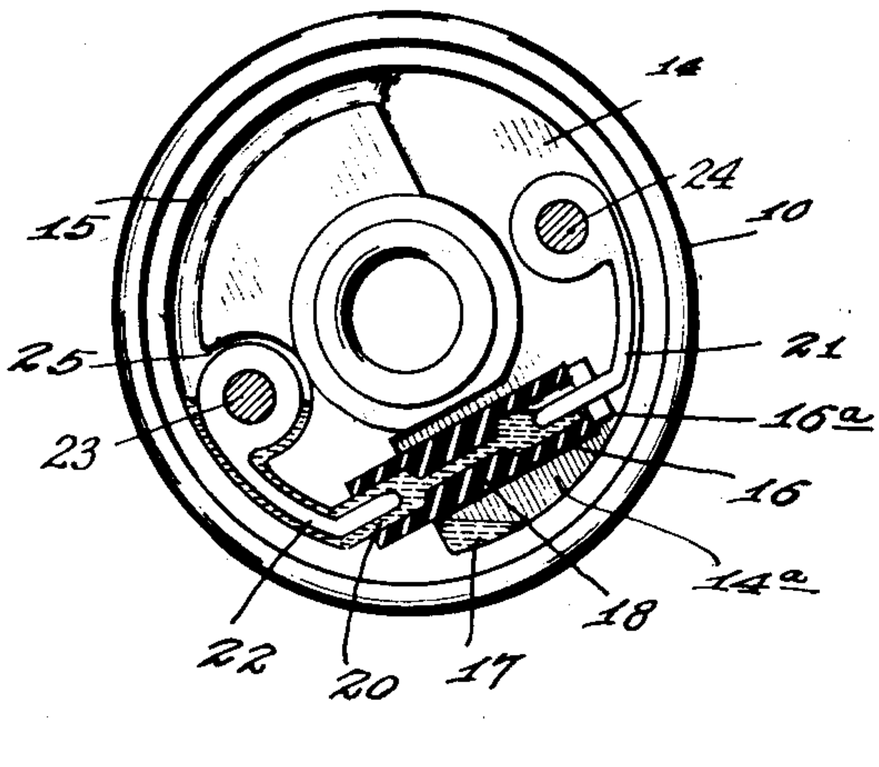
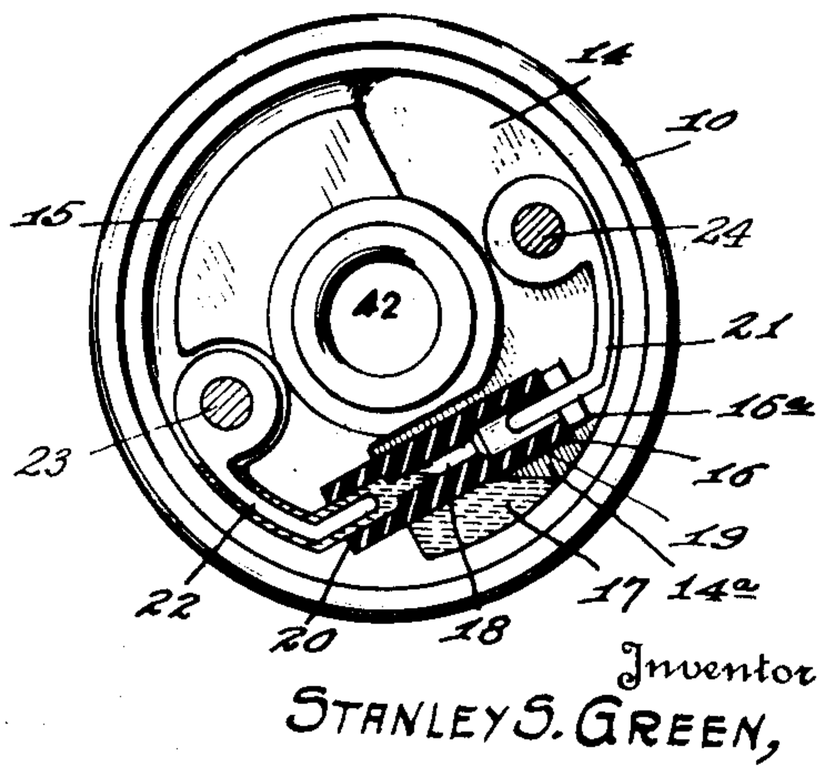



Fig. 6.

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# UNITED STATES PATENT OFFICE

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## CIRCUIT CONTROLLER

Application filed June 13, 1928. Serial No. 285,114.

It is the general object of my invention to produce a dependable liquid-conductor reclosable cutout or circuit controller for electric circuits, desirably operable both automatically and manually to open such a circuit but requiring a certain definite movement or movements in order to close the circuit.

In practicing my invention, in the preferred way, I produce a reclosable cutout which will act automatically to break the circuit at a definite current value with an action similar to that of a fuse and which may also be operated as a switch to break such circuit, which upon certain definite movements will positively reclose the circuit which it has broken and will only do so upon those definite movements so that once the circuit is broken it cannot be automatically or accidentally reestablished, which will do this without the necessity of renewing any of its parts, which has no relatively movable parts within it other than the liquid conductor itself, which provides a current-limiting portion of liquid conductor of definite cross-section, so that upon excessive current a vaporizing of such liquid conductor takes place at a definite current value to disrupt the current path and to displace the liquid conductor in such a manner that it cannot flow back to re-establish such path until the device as a whole is given the proper movements, which upon proper movements of the device provides a sufficient hydrostatic head to force the liquid conductor through the opening of limited size which provides said first-named portion of liquid conductor of definite cross-section, and which requires but a small amount of the liquid conductor, to make the device foolproof so that it is incapable of improper manipulation and so that in any position of the device the circuit cannot be maintained if the current value is beyond that for which the device is designed; and to accomplish these results by a structure which is safe, small, and inexpensive.

In carrying out my invention, I preferably use mercury as the liquid conductor; and place it within a holding means, desirably sealed, and including a main container and a smaller container or conduit, into which electrodes project, so that a circuit may be completed between them through the mercury. The mercury does not fill the holding means, but leaves considerable gas space to avoid excessive pressure upon vaporization of a portion of the mercury. The smaller container or conduit is provided with a tubular passage of definite cross-section, which tubular passage must be filled with mercury in order to complete the circuit between the two electrodes. Mercury may be withdrawn from the tubular passage by proper movement of the device as a whole, to break the circuit in a manner similar to the opening of a switch. In addition, if the circuit is closed by mercury in such tubular passage, an excessive current will cause vaporization of the mercury in such passage, and the resultant increase in volume forces the mercury out of the passage and thus disrupts the circuit. The tubular passage is so arranged with respect to the rest of the holding means that when the device is in circuit-closing or "normal on" position the mercury when once blown out of the tubular passage in the manner just described, thus breaking the circuit, cannot flow back into such passage to re-establish the circuit as long as the device remains in that position. To re-establish the circuit, the device must be moved to another or preliminary position, which is an "off" position, to cause the mercury to flow into a passage-feeding location; from which the mercury will flow into the passage, so that upon returning the device to circuit-closing or "normal on" position the circuit will be re-established. In the preferred form of my invention, which is the form illustrated, the flow of mercury into the passage does not occur until the movement from the preliminary or "off" position to the circuit-closing or "normal on" position. The passage is so arranged with respect to the rest of the receptacle that the flow of mercury into it is insured by the production of a sufficient hydrostatic head to overcome any tendency to prevent such flow, as by capillary action on the mercury.

The accompanying drawing illustrates my

invention in a preferred form, independently of any mounting and of any definite current-supplying means, as they may take many forms. In such drawing, Fig. 1 is a front elevation of a cutout or circuit controller embodying my invention; Fig. 2 is a section on the line 2—2 of Fig. 1; and Figs. 3, 4, 5, and 6 are front elevations of the cut-out of Fig. 1, with the front shell-part removed and with certain of the parts in section substantially on the line 4—4 of Fig. 2, showing the conditions and positions of the parts in the "off" position, an intermediate position between "off" and "normal on" position, the "normal on" position with the circuit closed, and the "normal on" position with the circuit blown open, respectively, the position shown in Fig. 4 corresponding to that illustrated in Figs. 1 and 2.

In this preferred form of my invention, there is an insulating shell formed of two mating parts 10 and 11, the latter fitting tightly within an annular groove 12 of the former. These shell parts may be of suitable insulating material, such as bakelite; and if desired may be sealed together, as with varnish. The two parts 10 and 11 provide between them a generally arcuate main container or chamber 14 of fairly large cross-section extending generally about 180°, and a feed conduit 15 also generally arcuate but of much smaller cross-section extending for the greater part of the remaining 180°. (The statements of degrees of extent of the chamber 14 and feed passage 15 are merely explanatory, and are not given as limitations.) The counter-clockwise end of the container or chamber 14, as viewed in Figs. 3 to 6 inclusive, is desirably in general in the shape of a funnel, to facilitate feeding from such chamber into the feed conduit 15. At the clockwise end of the container or chamber 14 a tube 16 of refractory insulating material is mounted, so that the only communication between the clockwise end of such chamber 14 and the counter-clockwise end of the feed passage 15 is through such tube 16. A suitable material for this tube is some heat-resisting glass, porcelain, or lava, as it is within this tube that the heat is generated upon the automatic blowing of the device. The tube 16 is supported at one end by fitting in mating recesses in the two shell-parts 10 and 11, and at that end communicates with the counter-clockwise end of the feed conduit 15; and is axially held in such recesses by an internally projecting lug or finger 16ª which is provided on a shell-part and bears against but does not close the other end of the tube. Thus save at the first-named end, the tube 16 projects into the chamber 14, and is spaced therefrom, so that a pocket 14ª is provided around the tube at the clockwise end of such chamber 14. This pocket around the tube 16 is desirably of sufficient size to contain all or nearly all of the mercury 17 which is placed in the device; so that mercury cannot enter the tube 16 directly from the chamber 14, but can only enter it from the feed conduit 15. The tube 16 is provided with an opening or tubular passage through it for its whole length, which tube opening at an intermediate portion 18 is restricted for a considerable distance to provide the current-limiting conductor of definite cross-sectional area when that portion of the tube is filled with mercury. This portion 18 of smaller cross-section communicates at both its two ends with larger portions 19 and 20, the latter being a continuation of the feed conduit 15. The current-capacity of the device depends on the cross-section and to some extent on the length of the portion 18. The parts 15, 20, 18, and 19 together form the passage of a conduit which opens at both ends into the main container or chamber 14. The feed conduit 15 and the tubular passage through the tube 16 may be of any desired shape in cross-section; and while such cross-section is normally circular it is by no means necessarily so.

It is especially to be observed that the mercury-containing passage 18, by being formed through a body that surrounds such passage substantially throughout the length of the passage, defines a limiting size of cross-section for the body of mercury within the passage. That is, the size and shape of this mercury body is defined so that it is of substantially unvarying current-carrying capacity. By thus surrounding the passage, the effect which gravity would have on the size of the cross-section at various points in an uncovered passage is eliminated; so that it becomes possible, and indeed preferable as is shown in the drawing, to set the passage in an inclined position, and secure the most effective operation of the device, while yet maintaining the shape and size of the mercury in the passage substantially undisturbed by such inclination.

Suitable electrodes 21 and 22 are exposed in the respective tube-portions 19 and 20, being shown as projecting into such tube portions. When the tube is filled with mercury, such mercury is in contact with the two electrodes 21 and 22, and completes the circuit between such electrodes by way of the thread of mercury in the contracted portion 18 of the tube. The two electrodes cannot be connected together within the device, regardless of the position of the device, save by the mercury thread extending through the portion 18. If breakage occurs, say of the tube 16, the circuit then cannot be closed; and breaking of the circuit occurs if the circuit happens to be closed at the time such breakage occurs.

The two electrodes 21 and 22 are desirably made of, or at least coated with, some metal

which resists amalgamation with the mercury; and are desirably of sufficient proportions that most of the heat of the electric current will be generated in the current-limiting thread of mercury, and there will be no danger of fusion of the electrodes. For instance, the electrodes may be made of iron, or of nickel-plated copper.

The electrodes 21 and 22, in the form of my invention shown, are mounted on studs 23 and 24, which respectively project into the chamber 14 and into an enlargement 25 at an intermediate point along the feed conduit 15, through bosses 27 and 28 provided on the face of the shell-part 10. These studs 23 and 24 may furnish the connection points for the device; which connections may be made in any suitable way, shown diagrammatically as two flexible wires 29 and 30 respectively attached to the studs 23 and 24 by binding screws 31 and 32, although this mode of making the connections to the electrodes 21 and 22 is merely illustrative of a great number of connection modes which might be used.

The inner ends of the studs 23 and 24 carry the electrodes 21 and 22. To that end, in the form of my invention shown, the inner parts of such studs are shouldered, and provided with threaded extensions which receive nuts 33 and 34, which clamp the supporting ends of the electrodes against the shoulders on said studs, with the other ends of such electrodes projecting into the two ends of the tube 16. The nuts 33 and 34 are shown as elongated beyond the threaded ends of the studs, to receive clamping screws 35 and 36 which cooperate through such nuts with the studs 23 and 24 to clamp the two shell-parts 10 and 11 together. The heads of the screws 35 and 36 are conveniently located in recesses in bosses 37 and 38 provided on the shell, and desirably have a fairly tight fit within such recesses to provide a seal to a considerable extent. Such seal may be made more effective if the heads of the screws on the inner walls of said recesses are freshly varnished just before the screws are set.

The device may be supported in any convenient manner, so that it may be turned, manually or otherwise, to the various positions illustrated in Figs. 3, 4, 5, and 6. This turning will be permitted by the mode of connection to the studs 23 and 24, which connection as shown is by flexible wires although that method of connection is merely illustrative. No complete mounting for the device is shown, as no particular form of mounting is essential to my invention; and indeed, in the broader aspects of my invention, no mounting at all is necessary. Merely for the sake of illustration, a supporting horizontal shaft 41 is shown in dotted lines extending through the central opening 42 with which the shell may be provided, but this manner of support through a central hole is not at all essential.

If desired, the air may be exhausted from within the container; or some inert gas, such as nitrogen, may be provided in place of such air.

In operation, the device is in the condition and position shown in Fig. 5 when the circuit is closed. This is the "normal on" position. Under that condition, mercury stands in the counter-clockwise end of the feed conduit 15, and extends therefrom through the tube 16 into contact with the electrode 21, so that the adjacent ends of the two electrodes 21 and 22 are both immersed in mercury, and the two electrodes are connected together. Indeed, the electrode 22 is wholly immersed in mercury, and the immersing mercury aids that electrode in carrying current. The excess of mercury is spilled over from the free end of the tube 16 into the pocket 14ª surrounding such tube, and lies in the bottom of such pocket, as is clear from Fig. 5.

To open the circuit manually, the device is tilted from the "normal on" position shown in Fig. 5 to the "off" position shown in Fig. 3. This tilting may be in either direction, clockwise or counter-clockwise; but would probably usually be counter-clockwise. This empties the mercury from the tube 16, and the mercury collects by gravity in the counter-clockwise end of the chamber 14; so that there is no connection between the two electrodes 21 and 22, and the circuit is broken. The breaking of the circuit occurs within the refractory tube 16.

To reclose the circuit, the device is turned from the "off" position shown in Fig. 3, through the position in Fig. 4, to the "normal on" position shown in Fig. 5. This causes the mercury to flow, by gravity, from the counter-clockwise end of the chamber 14, being directed by the funnel shape of that end, into the feed conduit 15, and therethrough into the tube 16, and through such tube to reconnect the two electrodes 21 and 22. As the device passes through the position shown in Fig. 4, where capillary action tends to prevent the flow of mercury through the contracted portion 18, a hydrostatic head of mercury is provided at the clockwise end of the feed conduit 15 and provides sufficient hydrostatic pressure to overcome such capillary action and force the mercury through such contracted portion. By having the feed conduit 15 small in cross-section, a large head is obtainable with a small quantity of mercury. As the device approaches the "normal on" position shown in Fig. 5, any excess of mercury is spilled over from the free end of the tube 16 into the pocket 14ª provided around such free end at the clockwise end of the chamber 14; and such spilled-over or excess mercury is shown in such pocket in Fig. 5.

If any sludge collects on the mercury, it will for the most part collect on the surface of the mercury in the "off" position shown in Fig. 3, and will rarely if ever enter the tube 16. If any does enter such tube, it will be forced out and through the tube in the manipulation of the device, by the hydrostatic head above referred to.

If an excess current flows through the cut-out, such as would cause the blowing of a fuse, it produces a vaporization of some of the mercury in the contracted portion 18 of the tube 16. The amount of current to produce this depends upon the cross-sectional area of the tube; so that the size of such contracted portion will depend upon the value of the maximum current to be permitted. Upon such vaporization, the mercury which is vaporized expands in volume and forces the mercury out of the tube 16. The mercury forced out toward the right (Fig. 5 or Fig. 6) drops into the pocket around the tube, as is clear from Fig. 6; from which pocket the mercury cannot return directly into the tube 16, because the pocket around the tube is of sufficient capacity to hold such blown-out mercury. Some mercury may and ordinarily does still remain in the counter-clockwise end of the feed passage 15 and the adjacent end of the tube 16, but not enough to extend to the electrode 21, and therefore not enough to re-establish the circuit. In this condition the circuit is open, although the device is still in "normal on" position.

In order now to re-establish the circuit, the device must be turned first substantially to the "off" position shown in Fig. 3, to dump the mercury from the aforesaid pocket $14^a$ (and indeed from the feed conduit 15) into the counter-clockwise end of the chamber 14; whereupon by turning the device clockwise from the position shown in Fig. 3 through that shown in Fig. 4 to the position shown in Fig. 5 the c rcuit is re-established in the manner already described; and this is done without the renewing of any part.

For the sake of clearness of explanation, I have indicated on Fig. 1 two arrows marked respectively "Normal on" and "Off", and have shown on the shell a line 50 which may be moved to those two positions. When the line 50 is opposite the "normal on" arrow, the shell is in the position shown in Figs. 5 and 6; while when it is opposite the "off" arrow, it is in the position shown in Fig. 3. When the circuit is opened manually, the device is moved to the "off" position shown in Fig. 3, with the line 50 opposite the "off" arrow. When the circuit is closed, the device is always in the position shown in Fig. 5, with the line 50 opposite the "normal on" arrow. However, the device may be in the "normal on" position shown in Figs. 5 and 6 and the circuit still be open; and that is the situation that exists following a "blowing" of the device, upon the flow of an excess current. When such "blowing" occurs, producing a condition such as shown in Fig. 6, it is necessary to move the device (either clockwise or counter-clockwise) substantially to the "off" position shown in Fig. 3, with the line 50 opposite the "off" arrow, and then to turn the device clockwise from the "off" position shown in Fig. 3 to the "normal on" position shown in Fig. 5, to make the line 50 travel clockwise from the "off" arrow to the "normal on" arrow. The closing of the circuit cannot be effected following a "blowing" save by a movement of the device from the "off" to the "normal on" position; which necessitates a preliminary movement to the "off" position.

If upon the closing of the circuit, the conditions which caused the excess of current still exist, the device will immediately "blow" again, and thus again break the circuit. Thus a permanent closing of the circuit cannot be effected so long as overload conditions exist.

However, like a fuse, the device does not operate upon small transient overloads. The excess current must be sufficiently great to produce vaporization of the mercury; so that there is a time lag in the "blowing" of the device that varies in inverse sense to the amount of the overload, just as in a fuse.

I have illustrated my invention only in one preferred form. The present application is intended not only to cover that preferred form but also is intended to cover the invention generically. For instance, one modified form of the invention, coming within the scope of my generic claims herein, is shown and claimed in my co-pending application Serial No. 317,221, filed November 5, 1928.

While in the specific emobdiment which I have illustrated of my invention the tube 16 and its restricted conduit passage 18 are within the space provided by the main container, so that any liquid conductor within such tube and its conduit passage are in a broad sense also within the container in which such tube is positioned, yet in the appended claims when a relation is expressed between liquid conductor in the conduit passage and liquid conductor in the container the latter liquid conductor refers to that which is in the container but not in the conduit passage.

I claim as my invention:—

1. An electric circuit controller, comprising a container movable to "off" and "normal on" positions, a conduit having a tubular passage communicating with said container, liquid conductor within the space provided by said container and conduit, and two electrodes exposed within said space and separated from each other lengthwise of said passage and positioned to be interconnectible within said space only by liquid conductor contained within and filling a predetermined length of said tubular passage between said electrodes to allow current flow for a sub-

stantial distance in a direction along said passage, said electrodes being located with relation to said container and conduit so that they are interconnected only when the container is substantially in the "normal on" position, and said conduit being so shaped and positioned with respect to the container that when the container is in "normal on" position and said predetermined length of said tubular passage is not filled with liquid conductor a flow of the liquid conductor from said container into said passage can be obtained only by first moving said container to the "off" position.

2. An electric circuit controller, comprising a container movable to "off" and "normal on" positions, a conduit having a tubular passage communicating with said container, liquid conductor within the space provided by said container and conduit, and two electrodes exposed within said space and separated from each other lengthwise of said passage and positioned to be interconnectible within said space only by liquid conductor contained within and filling a predetermined length of said tubular passage between said electrodes to allow current flow for a substantial distance in a direction along said passage, said electrodes being located with relation to said container and conduit so that they are interconnected only when the container is substantially in the "normal on" position, and said conduit being so shaped and positioned with respect to the container that when the container is in "normal on" position and said predetermined length of said tubular passage is not filled with liquid conductor a flow of the liquid conductor from said container into said passage can be obtained only by first moving said container to the "off" position, the tubular passage of said conduit opening into said container at a level sufficiently above the low point of the container when the latter is in the "normal on" position that any liquid conductor discharged from said tubular passage into said container cannot re-enter the tubular passage while the container remains in that position.

3. An electric circuit controller, comprising a container movable to "off" and "normal on" positions, a conduit having a tubular passage communicating at two separate places with said container, liquid conductor within the space provided by said container and conduit, and two electrodes exposed within said space and connectible externally to the circuit to be controlled and separated from each other lengthwise of said passage and positioned to be interconnectible within said space by liquid conductor contained within a predetermined length of said tubular passage between said electrodes to allow current flow for a substantial distance in a direction along said passage, said electrodes being arranged with relation to said container and conduit and to the circuit to be controlled so that the circuit is closed only when the container is substantially in the "normal on" position, and said conduit being so shaped and positioned with respect to the container that when the container is in "normal on" position and liquid conductor in said predetermined length of said tubular passage fails to interconnect said electrodes a flow of the liquid conductor from said container into said passage can be obtained only by first moving said container to the "off" position.

4. An electric circuit controller, comprising a movable container, a conduit having a tubular passage communicating with said container, liquid conductor within the space formed by said container and conduit, two electrodes exposed within said space and connectible to the circuit to be controlled and connectible together within said space by liquid conductor extending through a predetermined part of the passage of said conduit, said conduit being so arranged with respect to said container that the liquid conductor will flow into it from the container only when the container is in a definite range of positions and the circuit between the electrodes will be closed only when the container is in a different definite range of positions.

5. An electric circuit controller, comprising a movable container, a conduit having a tubular passage communicating with said container, liquid conductor within the space formed by said container and conduit, two electrodes exposed within said space and connectible to the circuit to be controlled and connectible together within said space only by liquid conductor extending through a predetermined part of the passage of said conduit, said conduit being so arranged that it has one opening which is always above the level of the liquid conductor in the container and another opening into which liquid conductor may flow from the container only when the container is in a definite range of positions.

6. An electric circuit controller, comprising a movable container, a conduit having a tubular passage communicating with said container, liquid conductor within the space formed by said container and conduit, two electrodes exposed within said space and connectible to the circuit to be controlled and connectible together within said space by liquid conductor extending through a predetermined part of the passage of said conduit, said conduit being so arranged that it has one opening which is always above the level of the liquid conductor in the container and another opening into which liquid conductor may flow from the container only when the container is in a definite range of positions and so that the liquid conductor can occupy

the predetermined part of said passage only when the container is in a different definite range of positions.

7. An electric circuit controller, comprising a movable container, a conduit having a tubular passage communicating with said container, a liquid conductor located within the space formed by said container and passage, two electrodes which may be connected to the circuit to be controlled and may be connected together within said space by said liquid conductor, said electrodes being so arranged that they are connectible together by said liquid conductor only when at the same time the container is in a given range of positions and liquid conductor is in said conduit, and said conduit being such that when the container is in that given range of positions the liquid conductor remains in the conduit to connect the electrodes so long as it remains liquid but no liquid conductor can flow into the conduit from the container.

8. An electric circuit controller, comprising a movable container, a conduit having a tubular passage communicating with said container, liquid conductor located within the space formed by said container and passage, two electrodes which may be connected to the circuit to be controlled and may be connected together within said space by said liquid conductor, said electrodes being so arranged that they are connectible together by said liquid conductor only when at the same time the container is in a given range of positions and liquid conductor is in said conduit, said conduit being such that when the container is in that given range of positions the liquid conductor remains in the conduit to connect the electrodes so long as it remains liquid, and said container and conduit being so arranged that liquid conductor can flow from said container into said conduit only when the container is moved to a different range of positions.

9. An electric circuit controller, comprising a quantity of liquid conductor, movable means for holding said liquid conductor so that the liquid conductor takes different positions according to the position of said holding means, two electrodes which may be connected to the circuit to be controlled and may be connected together by said liquid conductor, said electrodes being so arranged with respect to each other and to said holding means that they are connectible together by said liquid conductor only when at the same time the holding means is in a given range of positions and liquid conductor occupies a definite part of said holding means which it is impossible to fill or empty by gravity flow from or to the rest of said holding means while the holding means is in that range of positions, said definite part being of tubular form.

10. An electric circuit controller comprising a liquid container having a passage formed through a body that surrounds the passage susbtantially throughout the length of the passage and in communication with the container, said container being movable; a quantity of liquid conductor in said container; and two circuit electrodes at said passage and simultaneously engageable by liquid conductor contained in said passage, said liquid conductor being receivable into said passage from the container and being also dischargeable from the passage upon the flow of abnormal current through said electrodes and the liquid conductor between them, said container being shaped to hold the liquid conductor thus discharged and prevent its return to the passage when the container is in circuit-closing position, and also being shaped to direct return flow of such discharged liquid toward the passage when the container is moved from and subsequently returned to said circuit-closing position.

11. An electric circuit controller comprising a movable container having a normal circuit-closing position, a quantity of liquid conductor within the container, a tube of heat-resisting insulation having its passage communicating with the container, two electrodes arranged for connection to a circuit and connectible together by liquid conductor in and extending along a substantial portion of the length of said tube and so spaced apart that said liquid conductor forms between them a current-path carrying current lengthwise of said tube; said container, tube, and electrodes having a shape and relation (*a*) which limit the interconnection of said electrodes by liquid conductor to substantially the normal circuit-closing position of the container and to a current-path completable only through the aforesaid substantial portion of the length of the tube, and (*b*) which, upon the expulsion of the liquid conductor from the tube, prevent its return while the container is in normal circuit-closing position.

12. An electric circuit controller as set forth in claim 11, with the addition that said tube is positioned to have a cross-sectional portion of its passage between the electrodes a sufficient distance above the bottom in the container for all circuit-controlling positions of the container that if the tube breaks the entire body of liquid conductor may be held in the container without interconnecting said electrodes.

13. An electric circuit controller as set forth in claim 11, with the addition that said container, tube, and electrodes have a shape and relation which feed the liquid conductor from the container into the tube upon movement of the container from and its subsequent return to said normal circuit-closing position, and that said tube is positioned to have a cross-sectional portion of its passage between the electrodes a sufficient distance

above the bottom in the container for all circuit-controlling positions of the container that if the tube breaks the entire body of liquid conductor may be held in the container without interconnecting said electrodes.

14. An electric circuit controller comprising a movable container having a normal circuit-closing position, a quantity of liquid conductor within the container, a tube of heat-resisting insulation having its passage communicating with the container, two electrodes arranged for connection to a circuit and connectible together by liquid conductor in and extending along a substantial portion of the length of said tube and so spaced apart that said liquid conductor forms between them a current-path carrying current lengthwise of said tube; said container, tube. and electrodes having a shape and relation (*a*) which, upon the expulsion of the liquid conductor from the tube, prevent its return while the container is in normal circuit-closing position, and (*b*) which constrain passage of the liquid conductor from the container into the tube only upon movement of the container from and its subsequent return to said normal circuit-closing position.

15. An electric circuit controller comprising a movable container having a normal circuit-closing position, a quantity of liquid conductor within the container, a tube of heat-resisting insulation having one end communicating with the container, a conduit which interconnects the other end of said tube with the container, and two electrodes arranged for connection to a circuit and connectible together by liquid conductor in and extending along a substantial portion of the length of said tube and so spaced apart that said liquid conductor forms between them a current-path carrying current lengthwise of said tube; said container, conduit, tube, and electrodes having a shape and relative positioning which, upon the expulsion of the liquid conductor from the tube, prevent its return while the container is in normal circuit-closing position.

16. An electric circuit controller as set forth in claim 15, with the addition that said container, conduit, tube, and electrodes have a shape and relation which feed the liquid conductor from the container through the conduit and into the tube upon movement of the container from and its subsequent return to said normal circuit-closing position.

17. An electric circuit controller as set forth in claim 15, with the addition that said tube is positioned to have a cross-sectional portion of its passage between the electrodes a sufficient distance above the bottom in the container for all circuit-controlling positions of the container that if the tube breaks the entire body of liquid conductor may be held in the container without interconnecting said electrodes.

18. An electric circuit controller as set forth in claim 15, with the addition that said container, conduit, tube, and electrodes have a shape and relation which both limit the interconnection of said electrodes by liquid conductor to substantially the normal circuit-closing position of the container and to the liquid conductor within the tube, and feed the liquid conductor from the container through the conduit and into the tube upon movement of the container from and its subsequent return to said normal circuit-closing position.

19. An electric circuit controller as set forth in claim 15, with the addition that said container, conduit, tube, and electrodes have a shape and relation which limit the interconnection of said electrodes by liquid conductor to substantially the normal circuit-closing position of the container and to the liquid conductor within the tube, and that said tube is positioned to have a cross-sectional portion of its passage between the electrodes a sufficient distance above the bottom in the container for all circuit-controlling positions of the container that if the tube breaks the entire body of liquid conductor may be held in the container without interconnecting said electrodes.

20. An electric circuit controller as set forth in claim 15, with the addition that said container, conduit, tube, and electrodes have a shape and relation which feed the liquid conductor from the container through the conduit and into the tube upon movement of the container from and its subsequent return to said normal circuit-closing position, and that said tube is positioned to have a cross-sectional portion of its passage between the electrodes a sufficient distance above the bottom in the container for all circuit-controlling positions of the container that if the tube breaks the entire body of liquid conductor may be held in the container without interconnecting said electrodes.

21. An electric circuit controller as set forth in claim 15, with the addition that said container, conduit, tube, and electrodes have a shape and relation which both limit the interconnection of said electrodes by liquid conductor to substantially the normal circuit-closing position of the container and to the liquid conductor within the tube, and feed the liquid conductor from the container through the conduit and into the tube upon movement of the container from and its subsequent return to said normal circuit-closing position, and that said tube is positioned to have a cross-sectional portion of its passage between the electrodes a sufficient distance above the bottom in the container for all circuit-controlling positions of the container that if the tube breaks the entire body of liquid

conductor may be held in the container without interconnecting said electrodes.

22. An electric circuit controller, comprising a container movable to "off" and "normal on" positions, a conduit having a tubular passage communicating with the container, liquid conductor within the space provided by the container and conduit, two electrodes exposed within said space and positioned to be interconnectible along a path extending lengthwise through a current-limiting portion of said tubular passage by said liquid conductor when it is contained within said tubular passage, said container and conduit being provided with means to cause said liquid conductor to close the circuit to be controlled operable by moving the container from "off" to "normal on" position, and said conduit-passage opening into the container at two separate places, a portion of the conduit-passage near each of said places being above the liquid conductor level in the container when the container is in "normal on" position in a manner to prevent flow of the liquid conductor from the container into said passage when the container is in such "normal on" position.

23. An electric circuit controller, comprising a container, liquid conductor in the container, a conduit communicating with the container, and two electrodes exposed and spaced to be interconnectible along a path extending lengthwise of the passage of said conduit by liquid conductor within a predetermined current-limiting portion of said passage, said conduit having one end of its passage opening into the container above the liquid level in the container in a definite first position of the conduit and having the mouth of the other end of its passage opening into the container below the liquid level in the container in said definite first position, said conduit having mounting means and being movable on such mounting means to a definite second position in which said last-mentioned passage mouth is above the liquid level in the container, and said conduit being lower at an intermediate point than at points on either side of that point when it is in the second position so that it will retain liquid conductor by gravity in the predetermined passage-portion between electrodes when it is in the second position to interconnect the electrodes.

24. An electric circuit controller as set forth in claim 23, with the addition that the conduit and container are angularly together movable on the mounting means, and that the predetermined portion of the conduit passage between electrodes is higher than the liquid level in the container in all operating positions of the conduit and container.

25. An electric circuit controller, comprising a container, liquid conductor in the container, a conduit communicating with the container at each end of its passage, and two electrodes exposed and spaced to be interconnectible by liquid conductor along a path extending lengthwise through a predetermined portion of the passage of said conduit, said conduit having a liquid-receiving mouth at one end of its passage opening into the container below the liquid level in the container in a definite first position of the conduit, in which first position the predetermined passage portion between electrodes is above the liquid level in the container, said conduit being movable to a definite second position in which the liquid-receiving passage mouth is above the passage-portion between electrodes, and said liquid-receiving mouth being shaped to dip up liquid conductor and feed it through said conduit into said passage-portion between electrodes as the conduit is moved from the first position to the second.

26. An electric circuit controller as set forth in claim 25, with the addition that the conduit and container are together movable to said first and second definite operating positions, and that a part of said predetermined passage-portion between electrodes is positioned with reference to the container to be higher than the liquid level in said container when said conduit is in said definite second position.

27. An electric circuit controller, comprising a container, liquid conductor in the container, a conduit communicating with the container, and two electrodes exposed and spaced to be interconnectible by liquid conductor extending along a predetermined portion of the passage of said conduit, said conduit having mounting means and being movable about an axis on such mounting means to two definite positions in both of which one end of the conduit passage opens into the container above the liquid level in the latter, the other end of said conduit passage opening into the container above and below the liquid level in the latter when the conduit is in said two positions respectively, said conduit being shaped to contain liquid conductor by gravity in the predetermined passage-portion between electrodes when it is in the position where both its ends are above the liquid level in the container and being positioned to drain liquid conductor contained therein into the container in the other of said two positions.

28. An electric circuit controller, comprising a container, a tubular conduit opening at both ends into a common space in said container, said conduit having a passage-portion which is higher at one end than at the other when the circuit through the circuit-controller is closed and which includes a current-limiting portion of predetermined dimensions, liquid conductor within the

space provided by said container and conduit, and two electrodes associated with said conduit to be interconnectible by said liquid conductor extending through said current-limiting conduit-portion to provide a current path lengthwise thereof; said circuit controller being provided with means for feeding said liquid conductor at will into the aforesaid passage-portion at the lower end thereof.

29. An electric circuit controller having a movable member, and comprising a container, a tubular conduit opening at both ends into a common space in said container, said conduit having a passage-portion which is higher at one end than at the other when the circuit through the circuit controller is closed and which includes a current-limiting portion of predetermined dimensions, liquid conductor within the space provided by said container and conduit, and two electrodes associated with said conduit to be interconnectible by said liquid conductor extending through said current-limiting conduit-portion to provide a current path lengthwise thereof; the aforesaid passage-portion being associated with said movable member to have said liquid conductor fed into it at the lower end thereof and discharged from it respectively by different movements of said movable member.

30. An electric circuit controller having a movable member, and comprising a container, a tubular conduit opening at both ends into a common space in said container, said conduit having a passage-portion which is higher at one end than at the other when the circuit through the circuit controller is closed and which includes a current-limiting portion of predetermined dimensions, liquid conductor within the space provided by said container and conduit, and two electrodes associated with said conduit to be interconnectible by said liquid conductor extending through said current-limiting conduit-portion to provide a current path lengthwise thereof; the aforesaid passage-portion being associated with said movable member to have said liquid conductor fed into it at the lower end thereof by movement of said movable member.

31. An electric circuit controller having a movable member movable to "off" and "normal on" positions, and comprising a container, a tubular conduit opening at both ends within said container, said conduit having a current-limiting portion which is of predetermined dimensions and is higher at one end than at the other when said movable member is in "normal on" position, liquid conductor within said container and conduit, and two electrodes associated with said conduit to be interconnected by said liquid conductor extending through said current-limiting conduit-portion but otherwise insulated from each other; said current-limiting conduit-portion being associated with said movable member to have liquid conductor fed to it at its lower end when the movable member is moved from "off" to "normal on" position and to have liquid conductor discharged from it when the movable member is moved from "normal on" to "off" position.

32. An electric circuit controller having a movable member movable to "off" and "normal on" positions, and comprising a container, a tubular conduit opening at both ends within said container, said conduit having a current-limiting portion which is of predetermined dimensions and is higher at one end than at the other when said movable member is in "normal on" position, liquid conductor within said container and conduit, and two electrodes associated with said conduit to be interconnected by said liquid conductor extending through said current-limiting conduit-portion but otherwise insulated from each other; said current-limiting conduit-portion being associated with said movable member to have liquid conductor fed to it at its lower end when the movable member is moved from "off" to "normal on" position.

33. A liquid conductor current-limiting circuit controller, comprising a pair of electrodes, a conduit forming a passage open at both ends, part of said conduit comprising a body of heat-resisting insulating material having a current-limiting tubular bore therethrough forming a part of said passage, said passage being shaped to retain a liquid conductor therein and in contact with said electrodes by gravity when in a normal "on" position only, a casing completely enclosing said passage and said electrodes, and a body of liquid conductor within said casing; said casing forming an expansion chamber communicating with the open ends of said passage and extending sufficiently below portions of said passage when in its "on" position so that liquid conductor expelled from said passage will fall to a lower level in the chamber, and in all operating positions extending sufficiently below at least one electrode so that the electrodes can not be connected by said liquid conductor except longitudinally through said bore; said casing and included parts being rotatable to an "off" position in which the liquid conductor will flow from at least a portion of said bore and disconnect said electrodes, and being so constructed that liquid conductor can be fed into said bore to connect said electrodes only as said passage is rotated to said "on" position.

34. An electric circuit controller, comprising a container, liquid conductor within the container, two electrodes, and a conduit shaped so that it can hold liquid conductor

within it, said conduit including as a portion a refractory control tube having a current-limiting bore, and said circuit controller including liquid-conductor-carrying means movable at will to feed liquid conductor from the container through said conduit and into the control tube to connect the electrodes along a path extending longitudinally through the control tube, said container being adapted to act as a discharge chamber for liquid conductor ejected from the control tube.

35. An electric circuit controller, comprising a container, two electrodes, a quantity of liquid conductor, a refractory control tube having a current-limiting bore small enough to require an appreciable pressure to force liquid conductor through it, and a feed conduit communicating with one end of said bore and through which liquid conductor may be fed by hydrostatic pressure exerted by the weight of a long and relatively narrow column of liquid conductor as it is fed through the conduit, said control tube and feed conduit together forming a receptacle capable of holding liquid conductor and opening into the container at both ends, and said circuit controller including means to collect liquid conductor discharged from the control-tube bore and return it at will to said bore through the feed conduit.

36. An electric circuit controller, comprising a container, two electrodes, a quantity of liquid conductor, a refractory control tube having a current-limiting bore, and a feed conduit communicating with one end of said bore, said control tube and feed conduit together forming a receptacle capable of holding liquid conductor and opening into the container at both ends, and said circuit controller including means to collect liquid conductor discharged from the control-tube bore and operable at will to return it to said bore through the feed conduit in order to connect the electrodes by liquid conductor and to withdraw liquid conductor from the control-tube bore in order to disconnect the electrodes.

37. An electric circuit controller, comprising a container, two electrodes, a quantity of liquid conductor, a refractory control tube having a current-limiting bore, and a feed conduit communicating with one end of said bore, said control tube and feed conduit together forming a receptacle capable of holding liquid conductor and opening into the container at both ends, and said circuit controller including means to collect liquid conductor discharged from the control-tube bore and operable at will to return it to said bore through the feed conduit in order to connect the electrodes by liquid conductor and also operable at will to break the circuit to be controlled.

In witness whereof, I have hereunto set my hand at Indianapolis, Indiana, this 12th day of June, A. D. one thousand nine hundred and twenty eight.

STANLEY S. GREEN.